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CALIBRATION PROCEDURES AND PROTOCOLS FOR RADIATION SAMPLING PUMPS AND ALPHA-PARTICLE SCALERS

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CALIBRATION PROCEDURES AND PROTOCOLS FOR RADIATION SAMPLING PUMPS AND ALPHA-PARTICLE SCALERS

by

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ABSTRACT

Results of flowrate calibrations of radiation sampling pumps as well as efficiency calibrations of alpha-particle scalers have been compiled and analyzed for the past three to four years. Careful analysis of data shows no real deterioration of the pumps or any other time-related trends. There does appear, however, to be a high degree of variability from one pump calibration to the next. For this reason a calibration result analysis, that will help remove some of the uncertainties associated with pump calibrations, is suggested. Some comments are also given concerning alpha-scaler efficiency that supports frequent calibration and close scrutiny of these results.

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PROCÉDÉS ET MARCHE À SUIVRE CONCERNANT LA CALIBRATION DES POMPES D'ÉCHANTILLONNAGE ET DES COMPTEURS DE PARTICULES ALPHA

par

M.G. Grenier* et A.J. Frattini**

RÉSUMÉ

Au cours des trois ou quatre dernières années, on a procédé à la compilation et à l'analyse des résultats relatifs à l'étalonnage du débit des pompes d'échantillonnage et à l'efficacité des compteurs de particules Alpha. Suite à une analyse minutieuse des données, on constate que les pompes n'ont subi aucune détérioration ou usure en raison de l'usage. Il semble toutefois y avoir un écart important entre les données relatives à l'étalonnage des différentes pompes. Par conséquent, on suggère de procéder à une analyse des résultats d'étalonnage, afin de dissiper les doutes à ce sujet. Le rapport présente aussi des remarques au sujet de l'efficacité du compteur de particules Alpha justifiant les nombreux essais dont il fait l'objet et la nécessité d'un examen minutieux des résultats.

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INTRODUCTION

The field grab sampling of airborne radioactive contaminants requires the use of a well calibrated pump and scaler. In the case of sampling pumps an accurate knowledge of sample volume through rotameter readings is necessary. Unfortunately, volume measurements are made in the field with instruments in which ruggedness and portability is achieved at some cost in accuracy and/or precision. Frequent calibration is needed to detect sudden or long term changes in pump characteristics. These changes could be caused by shocks, dirt accumulation, corrosion or diaphragm wear. Therefore, calibration should be performed at regular intervals to acnieve a knowledge of both short and long term behaviour.

The regular calibration of alpha-scintillation type scalers will help discern long and short term changes in instrument counting efficiency. These changes could be caused by aging, an unreliable high voltage supply, a contaminated or damaged scintillation screen or photomultiplier tube problems.

The present report deals with the interpretation of calibration results and suggests a new way of applying them.

H AND H PUMP CALIBRATION

CALIBRATING APPARATUS AND PROCEDURE

A wet test gas flowmeter (WTGM) was used over a period of approximately three years to calibrate H and H Custom Work Radiation pumps labelled 1 to 3. When in the process of being calibrated, the pumps are powered by a reliable power supply (Fig. 1). The WTGM has to be inspected prior to every calibration run. This includes checking and adding distilled water when needed as well as ensuring that the instrument is level (1). It is important to check the filter holder and to insert a new filter of the type normally

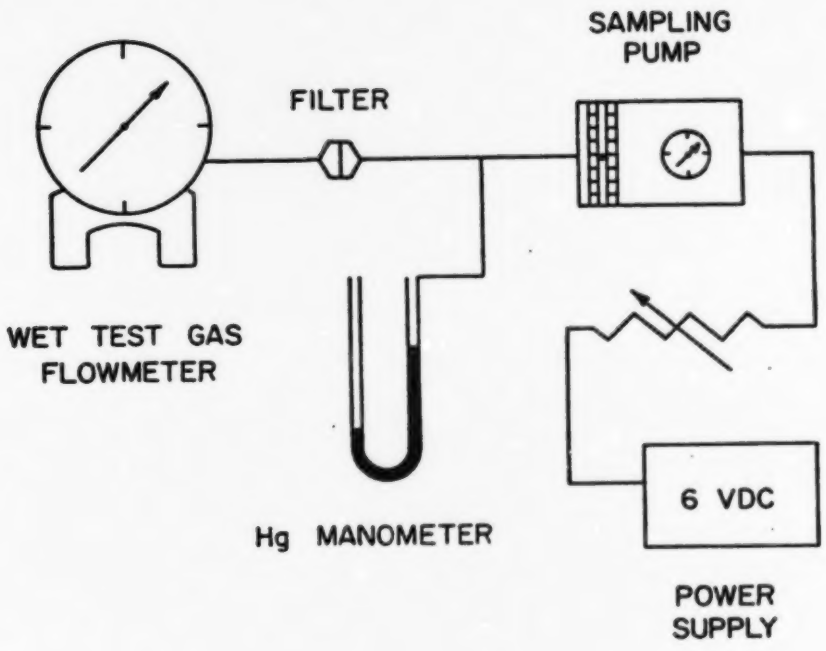

Fig. 1 - Radiation sampling pump calibration apparatus.

used, since a different pressure drop across the filter will affect calibration results. The effect of pressure drop variations across the filter associated with the use of different filter media, for actual pump calibrations, is demonstrated in Fig. 2. After the pump is connected to the power supply the voltage is adjusted until the pump rotameter reads approximately 5.0 L/min. Care must be taken to ensure accuracy of rotameter reading and avoid parallax reading error which could lead to differences in calibration curves such as that shown in Fig 3. This figure shows actual calibrations performed by the same person on two consecutive days, notice the curves are displaced, but remain parallel to each other as opposed to the lines shown in Fig. 2.

Once the pump is turned on and the flow seems to be constant, one complete revolution of the WTGM needle may be timed. This measurement should be repeated to verify the first reading. The voltage is then increased in regular increments until the rotameter reads approximately 7.5 L/min. Note that a good calibration curve should consist of at least 6 points (or one point approximately every .5 L/min.). The real flow rate Q_T may then be plotted as a function of the rotameter flow rate Q_{ROT}. Later, a linear regression analysis will yield the slope (m), the y-intercepts (b) as well as the square of the correlation coefficient (R^2).

LONG-TERM ANALYSIS OF PUMP CALIBRATIONS

Figure 4 shows a total of nine calibration curves for H and H pump No. 1. These calibrations took place between Sept. 1980 and May 1984. From this figure we see that the slope is fairly constant in most cases. Closer examination, however, uncovers one or two lines that seem to differ by a considerable amount. These odd curves are undoubtedly the result of carelessness during pump calibration. It may be that two filters were placed

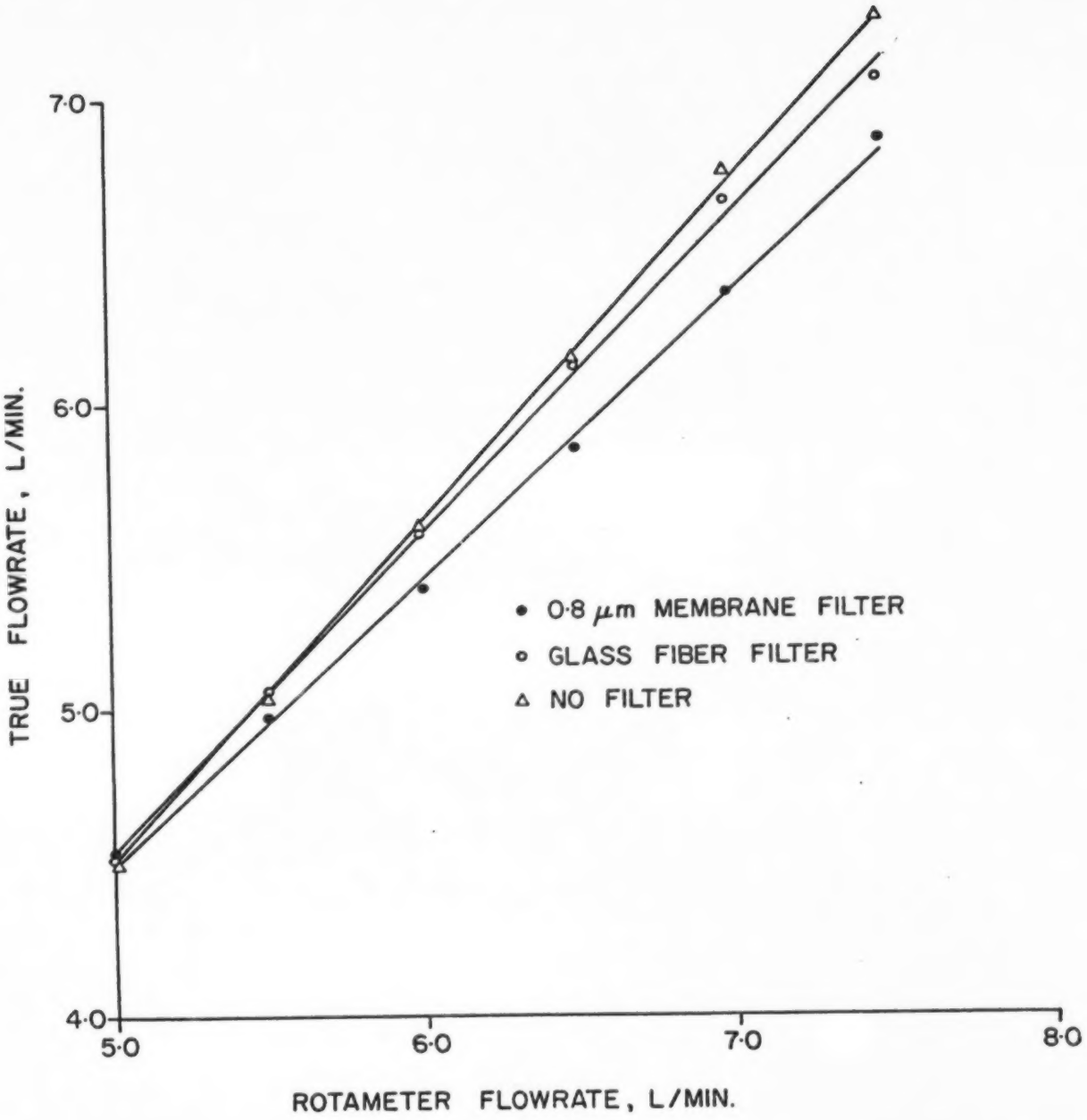

Fig. 2 - Calibrations performed on the same pump on the same day demonstrate the effect of varying the pressure drop across the filter holder by using different filter media (H and H pump No. 1).

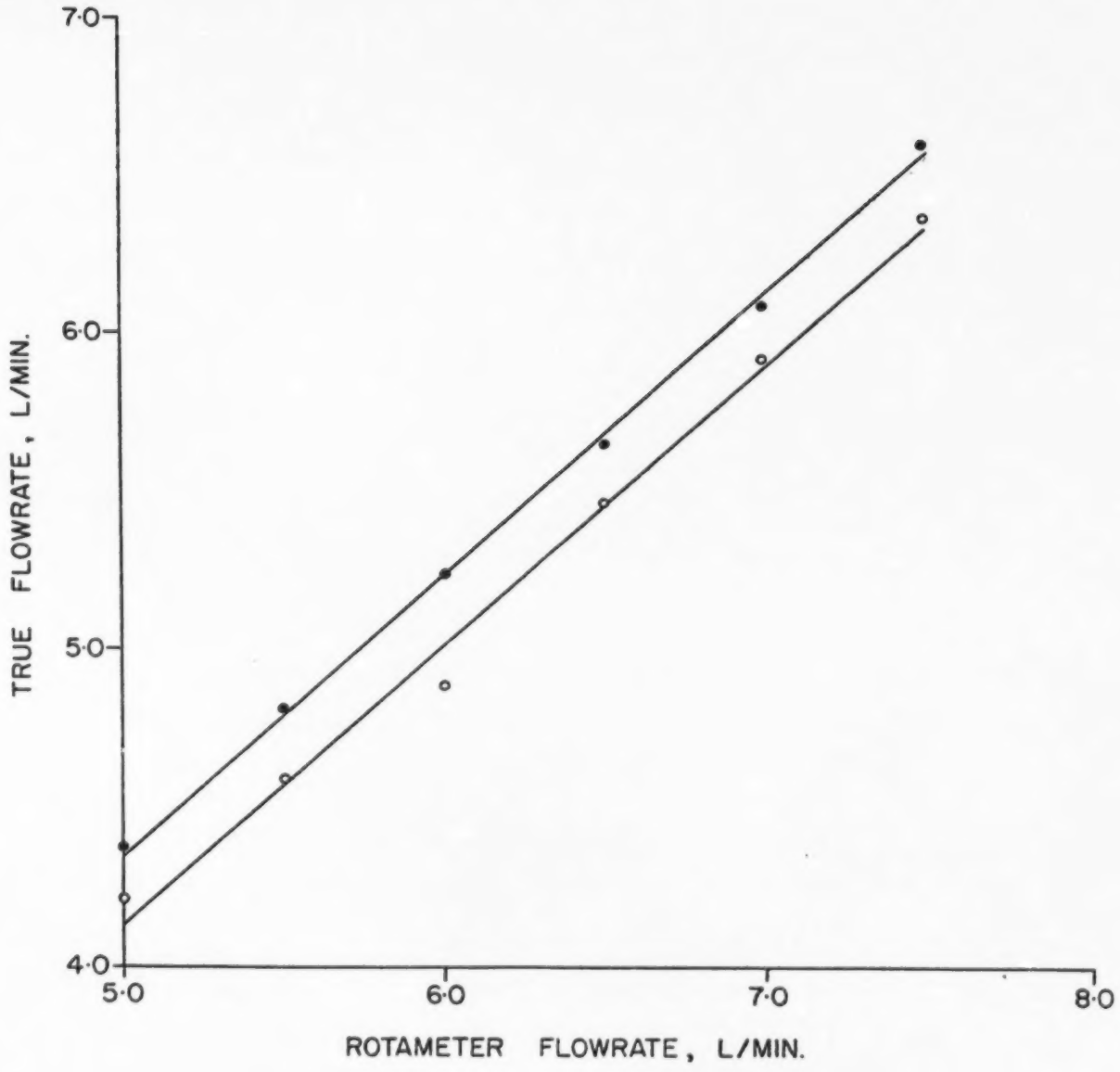

Fig. 3 - Calibrations performed using the same .8 µm membrane filter (H and H pump No. 2).

in the filter holder or the WTCM was not level, or water was missing. It may also have been extreme carelessness in reading the rotameter or a combination of the above. In retrospect, the reason for the discrepancy is not as important as the fact that we realize now, after having done more calibrations, that some calibrations are doubtful. At the time of calibration, however, it was not immediately obvious that the calibration might have been done carelessly. A set of rules is needed that will help us to accept or reject a given set of calibration tests upon examining the slope and correlation coefficent.

Another observation from Fig. 4 is the fact that there seems to be no consistent change in slope with time. Because of this, and in order to protect ourselves from uncertain calibrations, it is suggested that the following criteria be used to determine the integrity of any given calibration figures. Using all available records to date, the average slope of calibration lines was calculated along with a value of standard deviation for each pump. A satisfactory calibration would be one for which the slope lies in the range defined by the standard deviation about the mean. Also a value of R^2 greater than .98 would imply proper calibration procedures. Table 1 shows these ranges for pumps No. 1 to 3. If the slope value falls outside these ranges or R^2 is less than .98, then the pumps should be recalibrated. If a careful recalibration of the pump does not lead to slope and R^2 values within the given limits, then further examination of the pump would be required.

It was mentioned that the slopes in Fig. 4 do not seem to display long term changes with time. Hence, in order to protect oneself against unavoidable calibration fluctuations brought about by parallax error and filter media inconsistency (2), the following procedure should be used. The

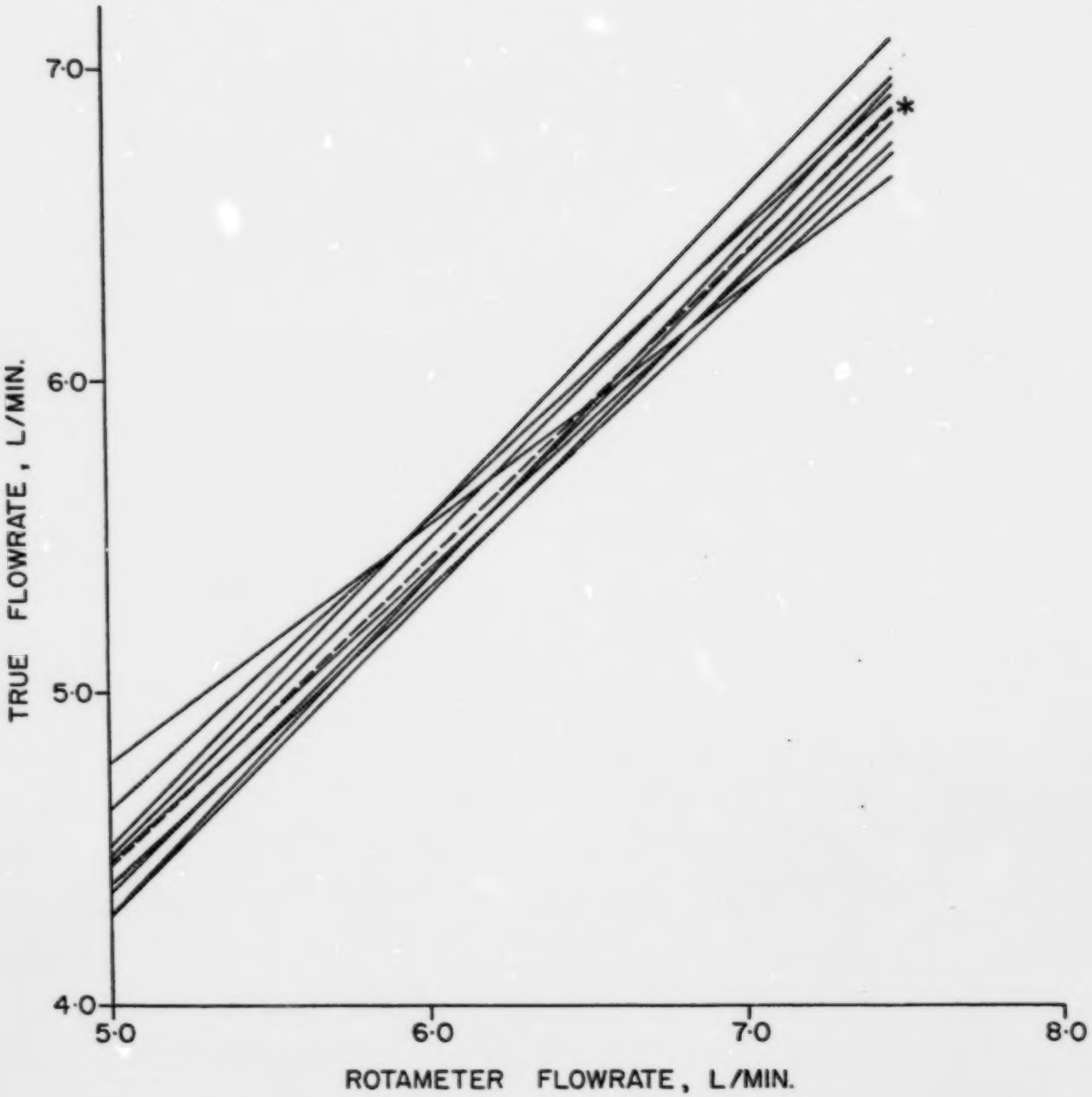

Fig. 4 - Calibrations done on pump No. 1 from Sept. 1980 to May 1984. The highest and lowest slope lines were disregarded and the rest were averaged (see text) to yield the line denoted by an asterisk.

Table 1 - Acceptable ranges of calibration curve slope for pumps No. 1 to 3

H & H Pump No.	$\bar{m} \pm$ S.D.	Range
1	.968 ± .091	.877 - 1.059
2	.938 ± .075	.863 - 1.013
3	1.138 ± .095	1.043 - 1.233

highest and lowest slopes should be discarded and the remaining slopes should be averaged along with the corresponding y-intercepts. Table 2 summarizes these figures for H and H pumps No. 1 to 3. In Fig. 4, the broken line is the above mentioned average line for H and H pump No. 1. It is felt upon examining Fig. 4 that in view of the random nature of the slope variation the average of slopes and intercepts is more reliable than any individual value. It is suggested, however, that calibration be performed on a regular basis (monthly) and that figures of Tables 1 and 2 be updated every six months in order to pick up any sign of long-term deterioration.

ALPHA-SCALER CALIBRATION

CALIBRATION APPARATUS AND PROCEDURES

TRIMET scalers, model TM-372A consist of a disc screen coated with zinc sulphide, a scintillating material. Alpha-particles striking this screen will cause photons to be produced that will be detected by a photomultiplier tube (PMT). The scaler is not perfectly efficient, i.e., the theoretical maximum efficiency of 50% in a 2π configuration can never be achieved. The attainable efficiency is not as important as the certainty with which it is known.

The efficiency is defined as the percentage of decays from a sample that is detected by the scaler and appears as a count on the face of the instrument. The standard used here is an Americium source (Am-241) calibrated at 4110 decays per minute (dpm) in April 1979, hence the efficiency is calculated as:

$$e = \frac{cpm}{dpm} \exp(.0016Y) \qquad \text{Eq 1}$$

Table 2 - Average of slope and y-intercepts for each pump to date (highest and lowest slope calibrations not included)

H and H Pump No.	$\bar{m}$	$\bar{b}$
1	.985	-.489
2	.949	-.448
3	1.135	-1.588

where, cpm is the count rate (per minute)

dpm is the decay rate (per minute)

Y is the elapsed time in years since April 1st, 1979.

LONG-TERM ANALYSIS OF SCALER EFFICIENCY CALIBRATIONS

It is considered good practice to calibrate scalers regularly (monthly) and to study such records from time to time so as to discern potential problems. Figure 5 shows the efficiency as a function of time for these scalers. Calibration records go as far back as 1980. For scalers No. 2 and 3 the efficiency is seen to be very stable with time. The efficiency of scaler No.1 however is more uncertain. The source of high voltage might be at fault or the PMT might be becoming less sensitive.

CONCLUSION

Factors like parallax reading error or filter media inconsistency as well as other possible intrinsic sources of error imply that calibration figures will possibly vary quite substantially from one calibration to the next. In order to eliminate the potentially large errors that could arise from these fluctuations, it is believed that the average of all calibrations (as outlined in the text) is a better estimate for the calibration of a given pump. As well, frequent efficiency calibration of Trimet scalers will help monitor the scaler's reliability on a short and long term basis.

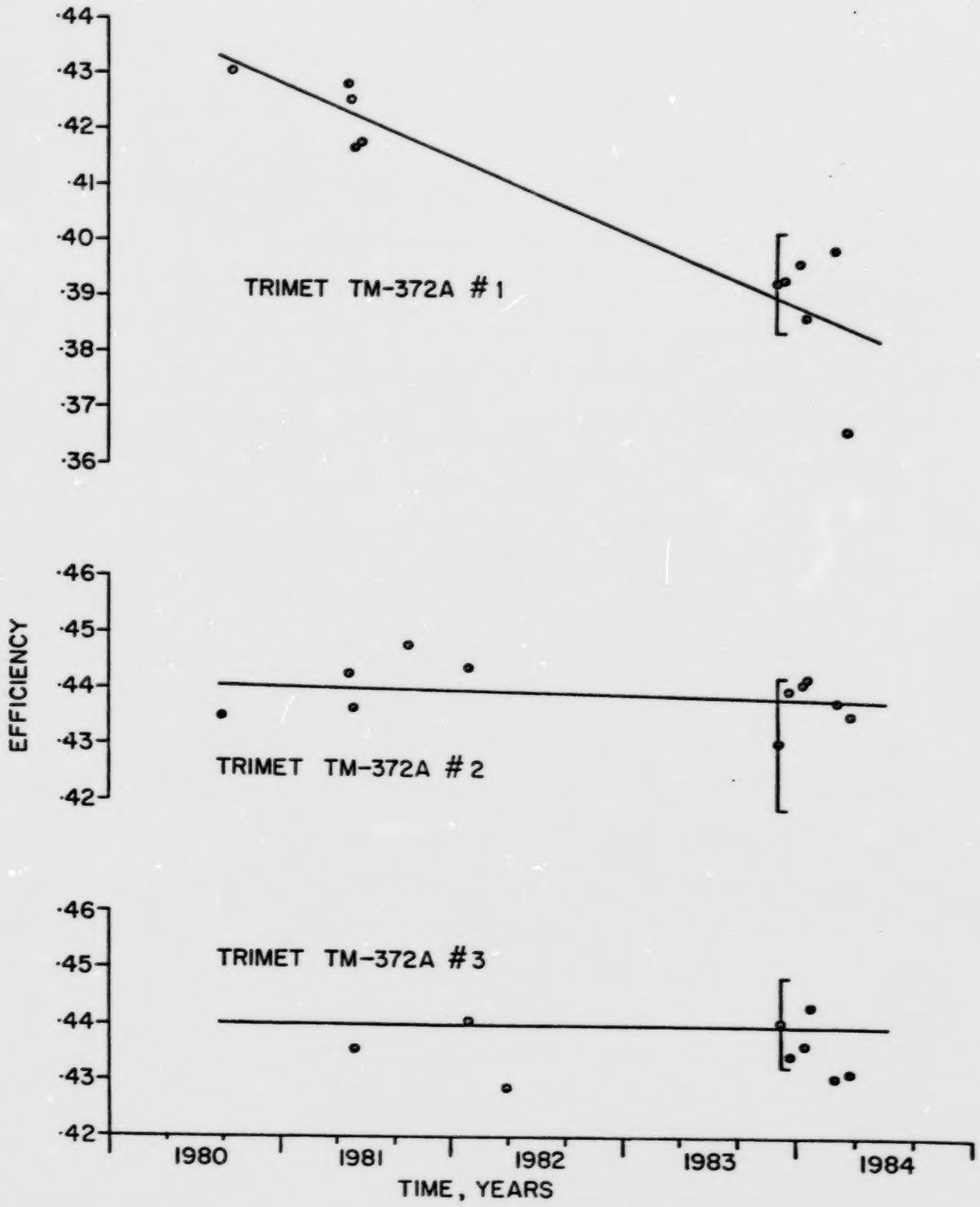

Fig. 5 - Scaler efficiency as a function of time for instruments No. 1 through 3. Typical error bars are included (standard deviation on ten trials).

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